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[54] **DEVELOPER MODULE WITH ELECTROMAGNETIC SHUTTER**

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[21] Appl. No.: **451,910**

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[51] **Int. Cl.**[6] **G03G 15/06**

[52] **U.S. Cl.** **355/253**; 118/657

[58] **Field of Search** 355/245, 253; 118/656, 657

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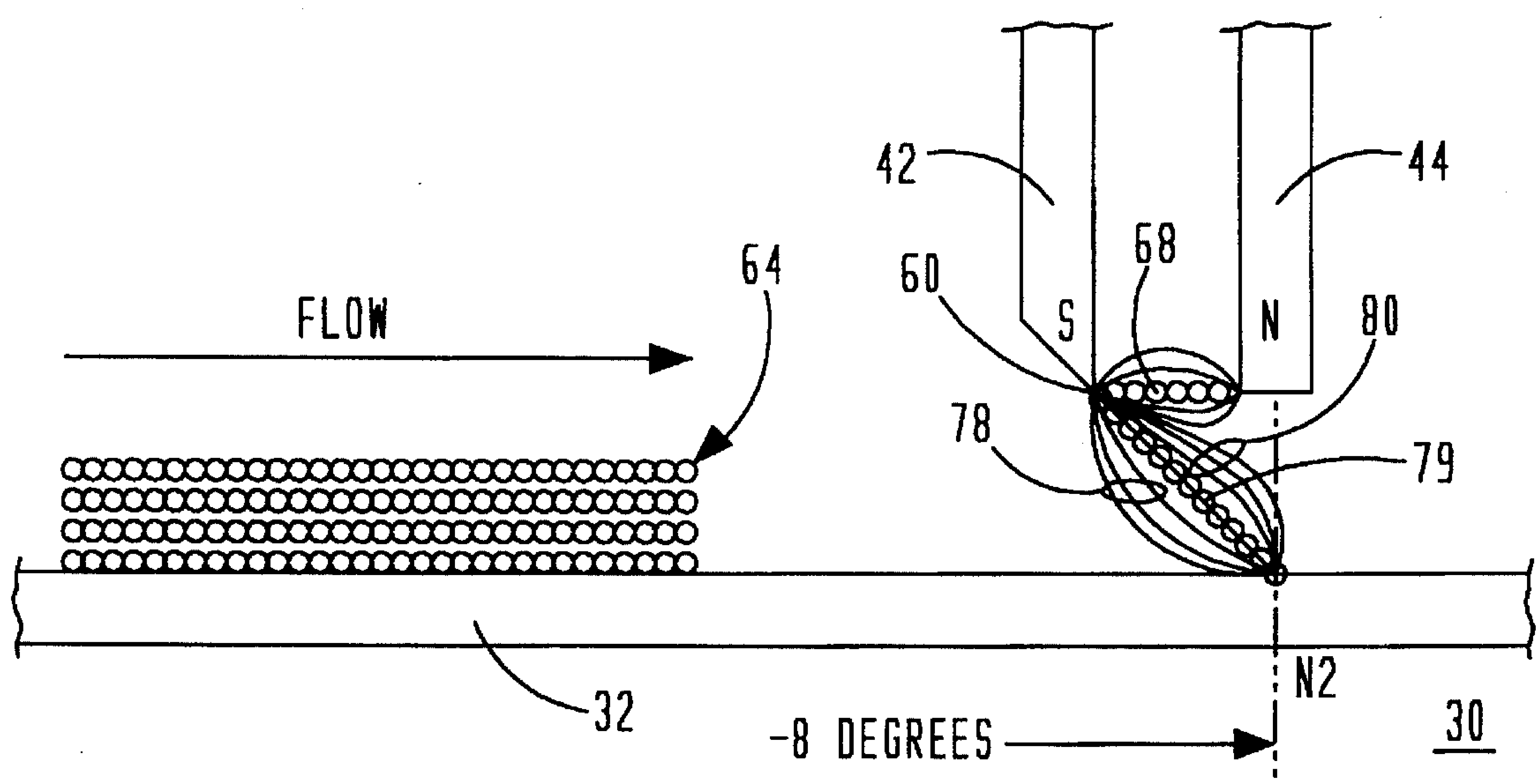
[57] **ABSTRACT**

An electromagnetic shutter (**40**) is comprised of two poles, a south pole (**42**) and a north pole (**44**) that are disposed above the surface of a delivery roller element (**32**). The delivery roller element (**32**) rotates about a fixed magnet (**30**) that has various poles. The south pole (**42**) of the electromagnetic shutter (**40**) is aligned proximate to the one of the north poles of the magnet (**30**). When the electromagnetic shutter (**40**) is activated with the windings (**48**) and (**50**) or winding (**48**) only, the shutter will form a magnetic dam (**79**) of toner particles which will effectively prevent passage of the toner particles thereby.

13 Claims, 5 Drawing Sheets



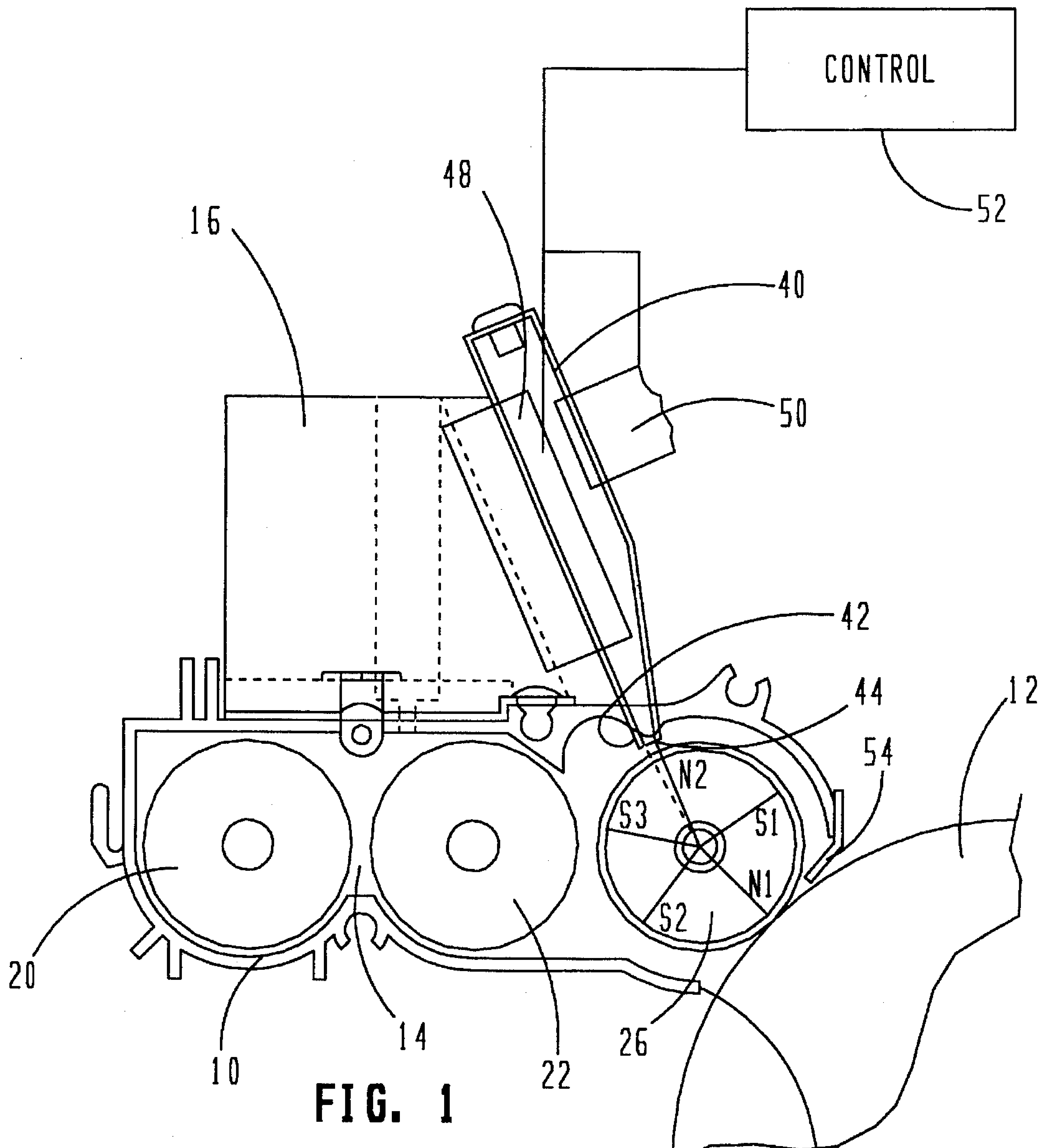

CONTROL
52
48
16
40
50
42
44
12
54
N2
S3
S1
N1
S2
20
10
14
22
26
28

FIG. 1

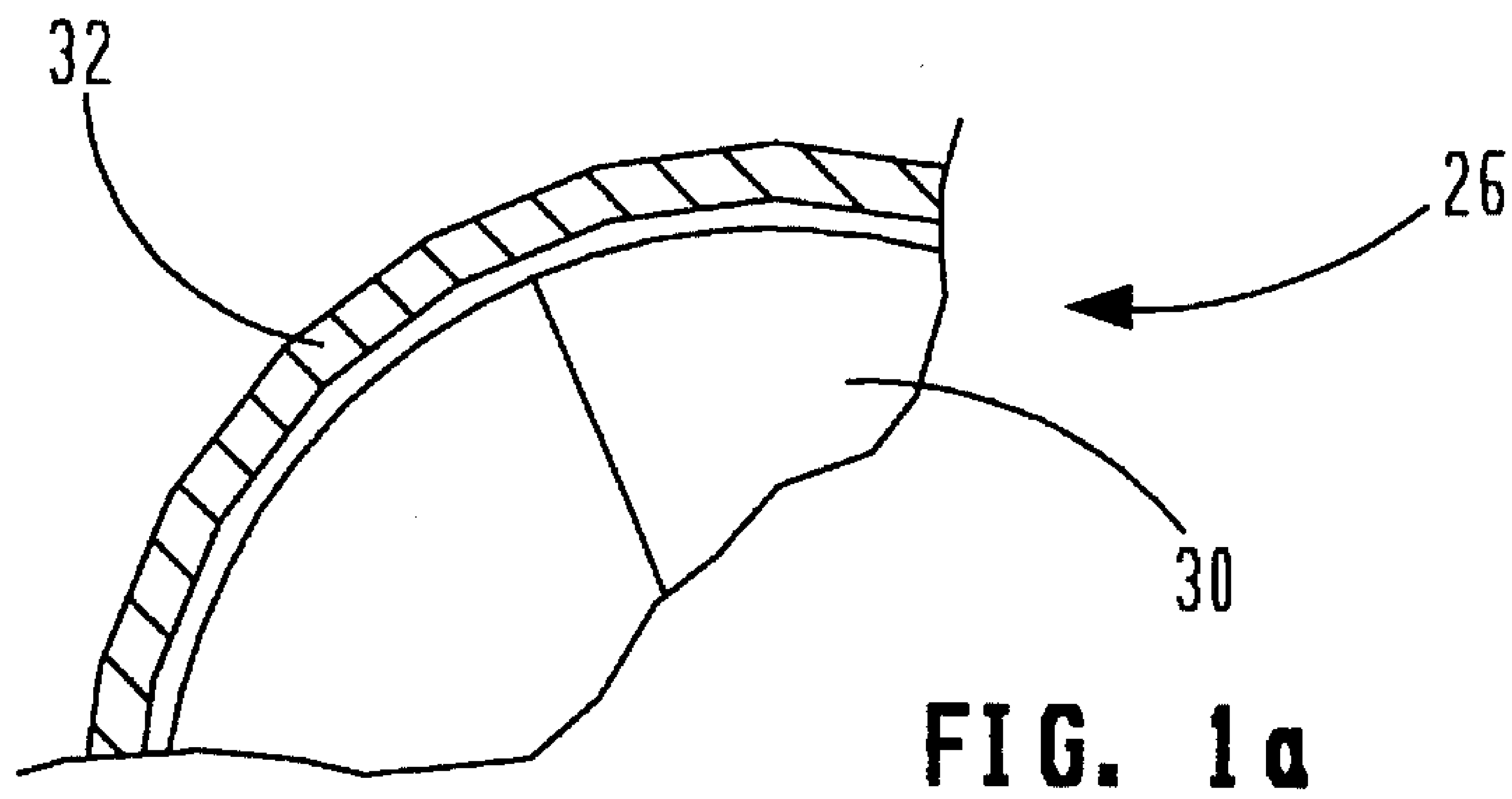

32
26
30

FIG. 1a

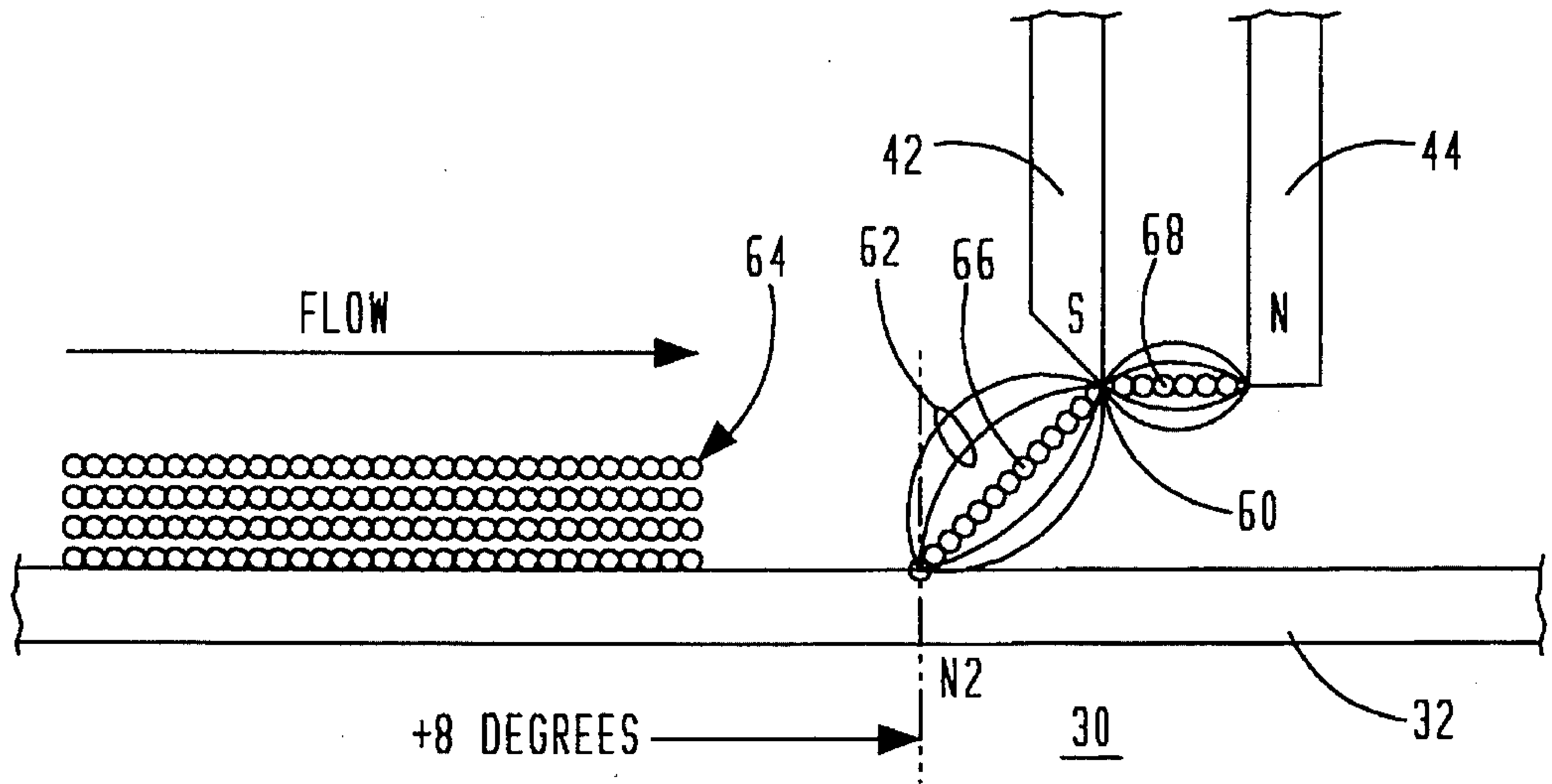


FIG. 2

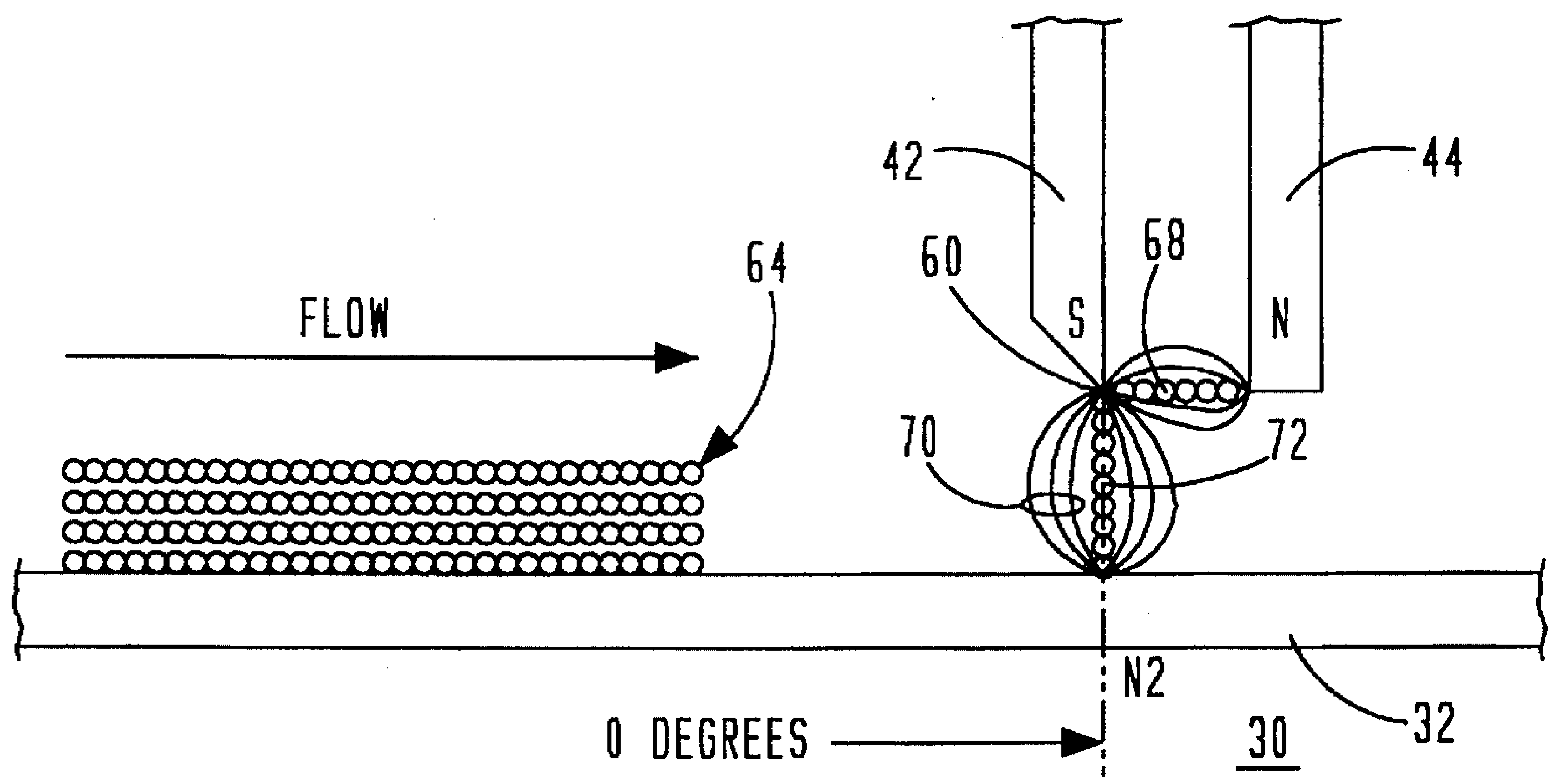


FIG. 3

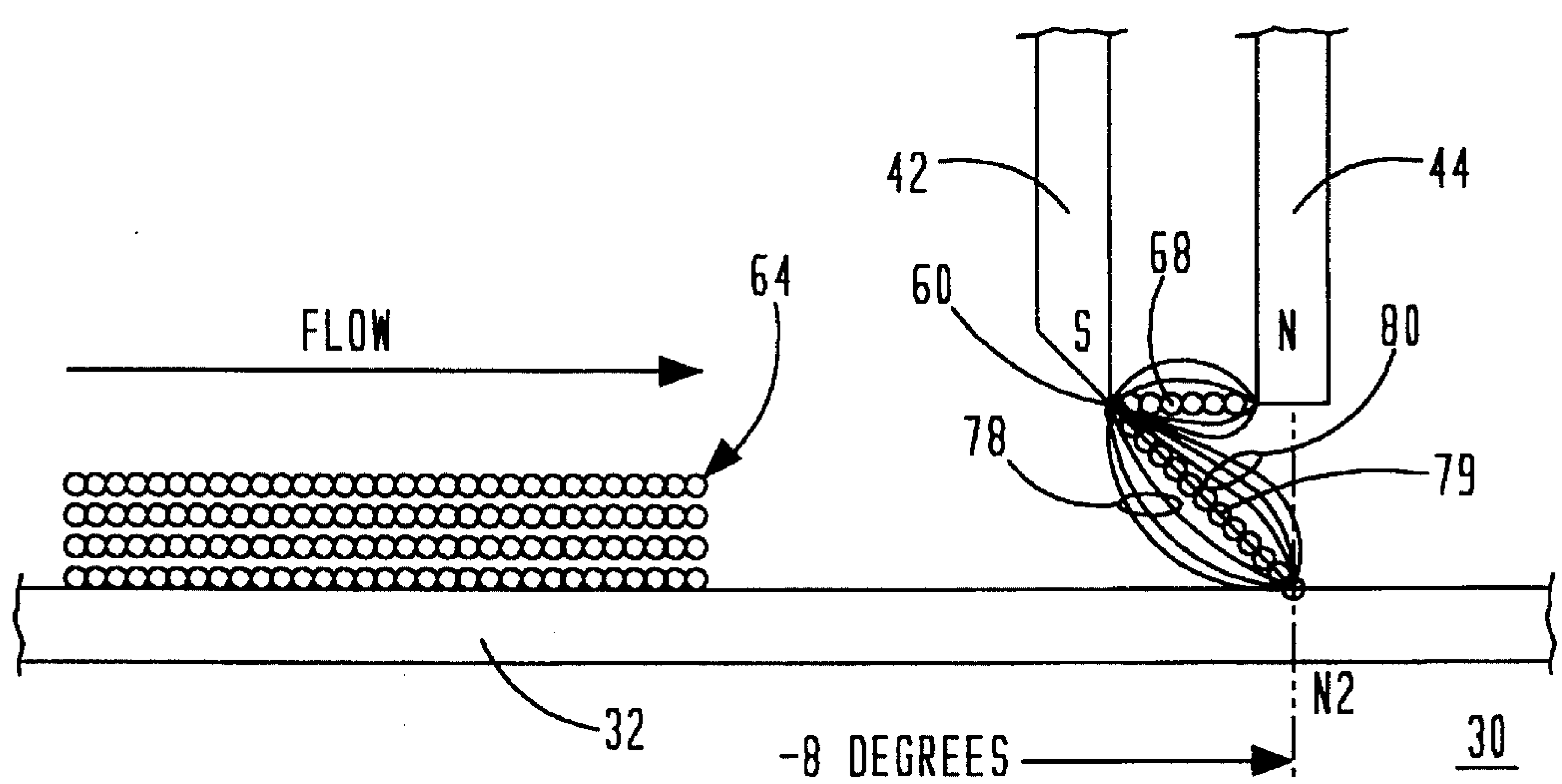


FIG. 4

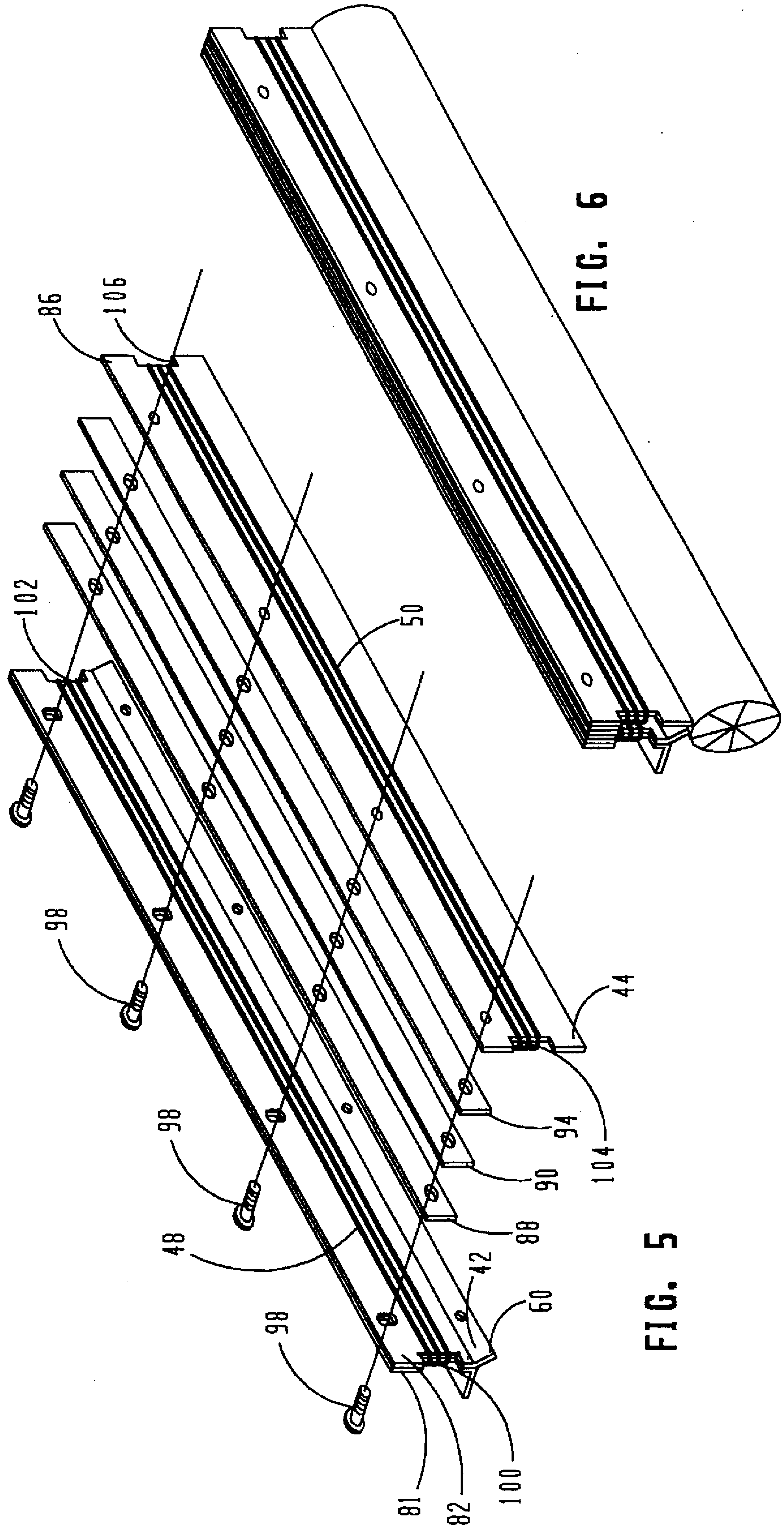


FIG. 5

FIG. 6

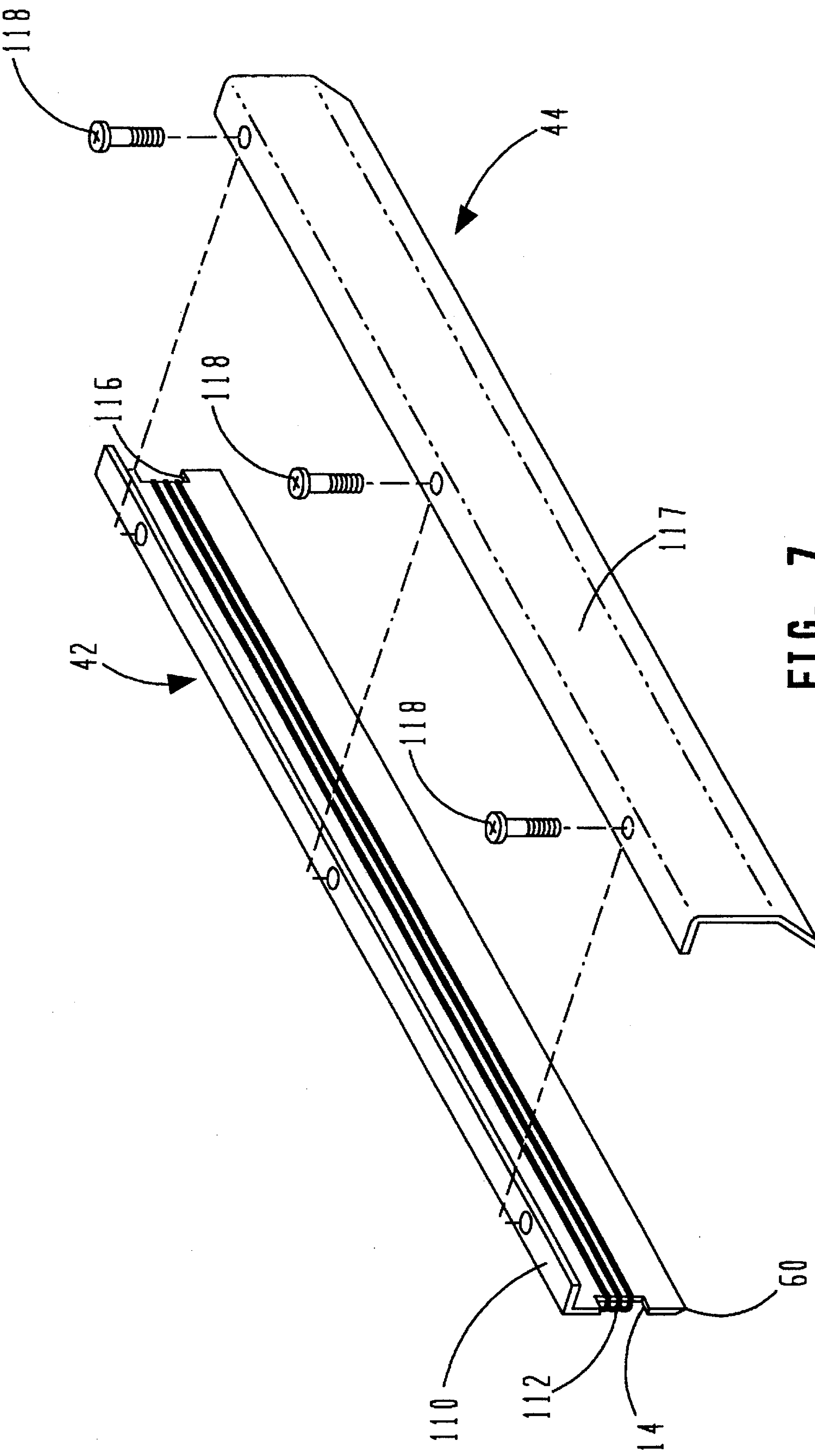


FIG. 7

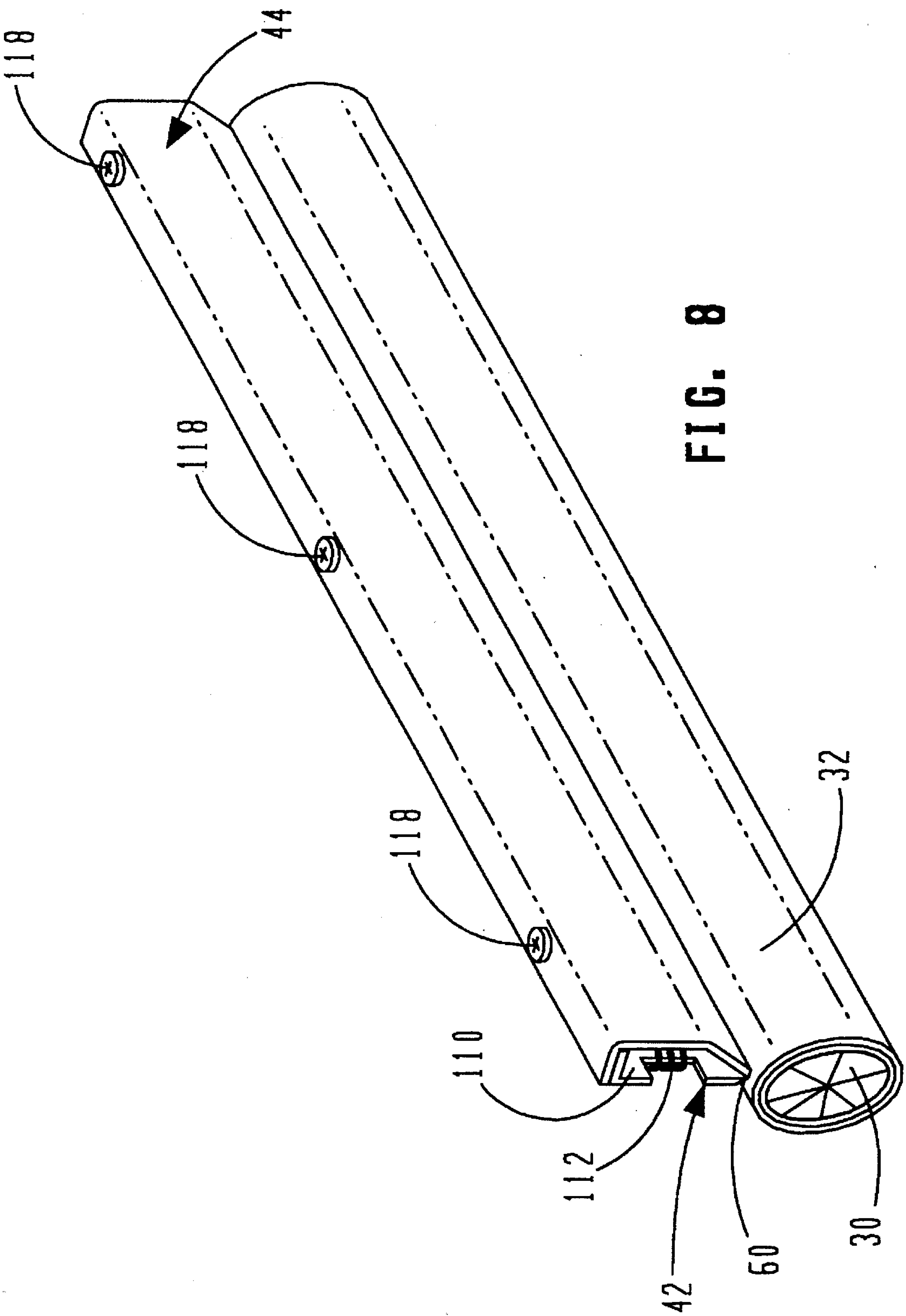


FIG. 8

DEVELOPER MODULE WITH ELECTROMAGNETIC SHUTTER

TECHNICAL FIELD OF THE INVENTION

The present invention pertains in general to a developer module for an electrophotographic print engine, and more particularly, to the distribution of developer from the developer module.

BACKGROUND OF THE INVENTION

In electrophotographic print engines, a latent image is first formed on a photoconductive member, which latent image has areas of differing electrical properties such that, when the latent image is passed by a supply of electrostatically charged toner particles, these toner particles will adhere to specific locations providing a "developed" image. This developed image can then be transferred to an image surface, such as paper, or an intermediate transfer member. For color reproductions, it typically requires the development of the latent image with different color toner particles.

The toner supply mechanism or developer is typically a reservoir of toner material that is continually mixed and disposed on a roller that rotates in contact with the photoconductive member when the latent image is passed thereby. However, most color designs today typically provide some type of shutter mechanism for preventing toner from being presented to the photoconductive member when the latent image is not present, as this will merely be removed from the photoconductive member by a cleaning blade at a later stage.

Presently, there are several methods used to shutter the developer flow, primarily dealing with mechanical methods to restrict flow. Most of these methods utilize mechanical blades or moving magnets. The mechanical blades allow the developer to be removed from the surface of the roller, thus preventing the toner particles from being developed on the photoconductive member. Since the developer particles have magnetic properties and can align themselves in a magnetic field, some systems utilized a system of moving magnets to allow the toner particles to be moved in contact with the photoconductive member or be inhibited from being presented thereto. Still, others move the developer mechanism away from the photoconductive member to avoid development. The disadvantage to these prior art systems is that they utilize mechanical moving parts.

SUMMARY OF THE INVENTION

The present invention, disclosed and claimed herein, comprises a developer module with an electromagnetic shutter. The developer module is comprised of a sump housing that is operable to contain electrostatic toner particles. The sump housing has an open end disposed therein for interfacing with a photoconductive element that is operable to carry a latent image. A delivery device is disposed in this opening with a moving surface for conveying toner from the interior of the sump housing to the photoconductive element. The delivery device has a fixed magnetic device associated therewith with at least one pole of a first polarity fixed relative to the movement of the surface of the delivery device. A magnetic damming device is provided that is operable to selectively create a magnetic field in the path of the developer flow along the surface of the delivery device to create field lines that extend upward from the surface of the delivery device from the at least one pole of the fixed magnetic device such that the developer particles align themselves with the created magnetic field.

In another aspect of the present invention, the delivery device is comprised of the hollow cylindrical roller disposed about a cylindrical fixed magnet. The fixed magnet has various poles disposed therearound and extending radially outward from the center thereof. This allows the toner particles to be magnetically aligned along the surface of the roller as it rotates. The magnetic damming device is comprised of an electromagnet having at least one pole of a second and opposite polarity to the first polarity of the fixed magnet. This one pole of the damming device is disposed above the surface of the delivery device by a predetermined distance and is switchable.

In a further aspect of the present invention, a second pole is provided on the damming device of the first polarity that is spaced away from the first pole thereof a predetermined distance to create field lines substantially parallel to the surface of the delivery device. The first pole of the damming device is disposed in a position that lags the first pole of the fixed magnetic device. This allows a magnetic dam to be disposed such that it is at an angle less than 90° with respect to the flow of magnetic developer particles.

BRIEF DESCRIPTION OF THE DRAWINGS

For a more complete understanding of the present invention and the advantages thereof, reference is now made to the following description taken in conjunction with the accompanying Drawings in which:

FIG. **1** illustrates a cross-sectional view of a developer module utilizing the electromagnetic shutter of the present invention;

FIG. **1***a* illustrates a detail of the distribution roller and magnet;

FIG. **2** illustrates a diagrammatic view of one orientation of the electromagnetic shutter;

FIG. **3** illustrates an alternate position to that of FIG. **2**;

FIG. **4** illustrates an alternate embodiment for FIGS. **2** and **3**;

FIG. **5** illustrates an exploded view of the electromagnetic shutter;

FIG. **6** illustrates a perspective view of the assembled electromagnetic shutter proximate to the distribution roller;

FIG. **7** illustrates an exploded view of the electromagnetic shutter with a single pole winding; and

FIG. **8** illustrates a perspective view of the assembled electromagnetic shutter with a single pole winding proximate to the distribution roller.

DETAILED DESCRIPTION OF THE INVENTION

Referring now to FIG. **1**, there is illustrated a cross-sectional view of a toner module utilizing the electromagnetic shutter of the present invention. The toner particles are generally contained within a toner module housing **10** and it is operable to be disposed adjacent a photoconductor (PC) drum **12**. However, it should be understood that any type of photoconductor member could be utilized, such as a belt, which would present a flat surface. The housing **10** includes a developer sump **14**, which is operable to contain toner material which, for a black and white electrophotographic print engine would be black toner, and for a color print engine, could be one of multiple colors, magenta, cyan, yellow. Additional toner is contained within a toner reservoir **16**, which is interfaced with the housing **10** such that toner would fall into the sump **14**. The sump **14** is operable to contain the toner to be delivered to the surface of the PC drum **12**. There are two stirring rollers **20** and **22** disposed within the sump **14** which are operable to ensure that the toner within the sump **14** is adequately uniform.

A delivery roller **26** is disposed on the end of the housing **10** proximate to an opening **28** within the housing **10**. A portion of the roller **26** on the outer peripheral surface thereof extends outward from the opening **28** and is disposed proximate to the surface of the PC drum **12**. The distance between the roller **26** and the PC drum **12** is sufficient to allow the properties of the latent image disposed on the surface of PC drum **12** to attract toner particles disposed on the surface of the delivery roller **26**.

A detail of the driving roller **26** is illustrated in FIG. **1***a*. The driving roller **26** is comprised of a permanent fixed magnet **30** that is "poled" such that there are various north and south poles disposed about the periphery thereof. The fixed magnet **30** is cylindrical in shape and has a hollow cylindrical outer roller member **32** manufactured from a material such as aluminum. This roller member **32** is rotatable such that it rotates at an equal or greater tangential speed as the surface of the PC drum **12** and in the opposite direction. In the embodiment illustrated in FIG. **1**, the driving roller **26**, rotates in a clockwise direction and the PC drum **12** rotates in a counter clockwise direction.

An electromagnetic shutter **40** is disposed in a fixed relationship with the housing **10** such that it is disposed on one edge thereof proximate to the surface of the delivery roller **26**. The electromagnetic shutter **40** has a south pole **42** and north pole **44**, the south pole **42** leading the north pole **44**. In the preferred embodiment, the tips of the two poles **42** and **44** are disposed away from the surface of the delivery roller **26** a distance of between one to two millimeters. Additionally, it is disposed proximate to the "north" pole of the permanent magnet **30**, the positioning thereof described herein in detail.

The electromagnetic shutter **40** has a single winding, **48**, disposed on the respective pole **42**. The electromagnetic shutter **40** is operable to be connected to a control system **52**, which control system **52** is operable to turn the electromagnetic shutter **40** on and off. The control system **52** can reverse the polarity of the electromagnet by changing the direction of the current applied to the windings which can produce the thickness of the developer flow to alter operating characteristics.

In operation, the delivery roller **26** is operable to have the outer roller member **32** rotate at a speed of approximately 200 millimeters per second. The toner particles are aligned along the tangential magnetic field on the surface of the roller member **32**, such that they will be delivered to the surface of the PC drum **12**. In order to prevent "clumping" of toner particles on the surface of the member **32**, a mechanical blade **54** is provided on the peripheral edge of the opening **28** of the housing **10** and disposed parallel to the delivery roller **26**. The blade **54** has a distal end that is disposed a distance of 0.6–0.7 millimeters away from the surface of a member **32** to provide a delivery gap.

Referring now to FIG. **2**, there is illustrated a diagrammatical view of the south and north poles **42** and **44**, respectively, in proximity to the rotating member **32** and the magnetic field associated therewith. The poles on the permanent magnet **30** are illustrated as being poles N1, N2, S1, S2 and S3. Pole N2 is the most proximate to the tips of the poles **42** and **44** and pole N1 is disposed proximate to the opening **28**. Pole S1 is disposed between poles N1 and N2 and poles S2 and S3 are disposed sequentially between N1 and N2 in that order. It is the relationship of pole N2 to the south pole **42** of the electromagnetic shutter **40** that is important for the present invention. The south pole **42** is noted as having a sharp point **60** disposed on the edge of the south pole **42** proximate to the north pole **44**. In the embodiment of FIG. **2**, the north pole N2 of the magnet **30** is at a position of approximately +8°, the "+" indicating a position relative to the south pole **42** of the electromagnetic shutter **40** that is "lagging" the flow, i.e. to the leer with a counter clockwise rotation. The field lines associated with the pole N2 and the south pole **42** at the tip **60** are denoted by a reference numeral **62**. Additionally, there are tangential fields that are the result of the north and south poles of the magnet **30**, these resulting in tangential field lines (not shown) along the surface of the member **32**. These tangential field lines allow toner particles **64** to align along the surface thereof. As they approach the field lines **62**, they will align between the north pole N2 and the south pole **42** to create a "dam" **66**. Additionally, some toner particles **68** will be disposed between the south pole **42** and the north pole **44** along the field lines between the gap therein. Therefore, whenever the electromagnetic shutter **40** is turned on, the field lines **62** will be generated and cause a buildup of toner particles in the dam **66**.

Referring now to FIG. **3**, there is illustrated a similar configuration to that of FIG. **2**, with the exception that the south pole **42** is disposed in line with the north pole N2 of the magnet **30**. This results in field lines **70** and a dam **72**, which is normal to the flow of the developer particles **64**, in addition to the position of the north pole N2 aligning with the sharp point **60** at the 0° reference position.

Referring now to FIG. **4**, there is illustrated an alternate embodiment wherein the pole N2 of the fixed magnet **30** "leads" the south pole **42**. In this manner, field lines **78** are provided between the pole N2 and the tip **60** of the south pole **42** to form a "dam" **79** of developer particles. This results in the field lines **78** proximate to the north pole **44** being "compressed". This is represented by a point **80** on the field line **78**. This compression is due to the field lines between the south pole **42** and the north pole **44** that create the string of toner particles **68**. As will be noted herein in with the description of test results, this pole position of −8° is the optimum pole position. It is believed that when the pole N2 is positioned prior to the poles **42** and **44** of the electromagnetic shutter **40**, that the resulting field lines between pole **40** and N2 are too weak to stop all developer flow. When the pole N2 of the magnet **30** is disposed in a line with south pole **42**, the field lines generated on the surface of the roller member **32** are also too weak to stop all developer flow. However, when the magnet pole N2 is positioned across from its similar pole, the north pole **44**, the "wedge" effect of the developer occurs. This results in the strongest field. This is due to the fact, it is believed, that the magnetic field of the two like poles reshape the field lines between the south pole **42** and the two north poles N2 and **44**. The compression of the field lines creates a dense lateral magnetic field between the N2 pole of the magnet **30** and the south pole **42** of the electromagnetic shutter **40**. The lateral magnetic field strength is increased and creates a wall of developer, the dam **79**, that has a larger force component to oppose the oncoming developer flow. The developer flow takes the path of least resistance and falls back into the developer sump **14**. This shearing effectively is maximized by the summation of magnetic field strength in the opposite direction of developer flow.

Various tests were performed at different currents, pole positions and gap widths. They are described hereinbelow with reference to Table 1–Table 9. For these experiments, the wire size used was a 28 AWG, and 30 AWG. Tables 1–6 use a combination of 28 and 30 AWG wound on south pole **42** with 310 turns of each wire. Tables 7–9 use only 30 AWG with a total of 517 turns on south pole **42**. Using a single pole for windings allowed for easier assembly and a smaller profile. The rating was as follows:

Below average: 1

Average: 2

Above Average: 3

Excellent: 4

TABLE 1

		CURRENT A				
GAP	POLE POSITION	0.14	0.21	0.27	0.33	0.41
1 mm	0°	1	1	2	3	4
1 mm	5°	1	1	2	3	3
1 mm	−5°	2	2	3	4	—
1 mm	−10°	2	2	3	4	4
2 mm	0°	1	2	2	3	3
2 mm	−5°	—	1	2	2	3
2 mm	5°	2	2	3	3	4

TABLE 2

	CUR-	POLE POSITION								
GAP	RENT	10	7	5	3	0	−3	−5	−7	−10
1 mm	0.3 A	4	4	4	3	3	3	3	4	4
1.5 mm	0.3 A	4	4	3	3	3	3	2	2	—
2.0 mm	0.3 A	—	—	3	3	2	2	2	2	2

TABLE 3

		POLE POSITION							
GAP	CURRENT	15	12	10	8	6	4	2	0
1.5 mm	0.3 A	2	2	2	2	2	2	2	2

TABLE 4

		POLE POSITION							
GAP	CURRENT	−2	−4	−6	−8	−10	−12	−15	−18.75
1.5 mm	0.3 A	3	4	4	4	4	4	4	4

TABLE 5

		CURRENT (A)							
GAP	POLE POSITION	0.3	0.28	0.26	0.24	0.22	0.2	0.18	0.16
1.5 mm	−8°	4	4	4	4	4	3	3	3

TABLE 6

		CURRENT (A)					
GAP	POLE POSITION	0.14	0.12	0.1	0.08	0.07	0.06
1.5 mm	−8°	3	2	2	2	1	1

TABLE 7

		POLE POSITION				
GAP	CURRENT	0	2	4	6	8
1.6 mm	0.3 A	2	2	1	1	1

TABLE 8

		POLE POSITION						
GAP	CURRENT	0	−2	−4	−6	−8	−10	−12
1.6 mm	0.3 A	2	3	3	3	4	4	4

TABLE 9

POLE POSITION	0	−2	−4	−6	−8	−10	−12
CURRENT (A)	0.4	0.4	0.4	0.3	0.3	0.3	0.3
RATING	3	3	3	3	4	4	4

Referring now to FIG. **5**, there is illustrated an exploded view of the electromagnetic shutter **40**. The shutter **40** is fabricated, as described above, from a south pole **42** and a north pole **44**. The south pole **42** is fabricated from two pieces of sheet metal core of a 1.5 millimeter stock with reference numbers **81** and **82**, the sheet metal piece **81** being a mounting block and the sheet metal piece **82** forming the south pole **42** at the lowermost peripheral edge thereof, this inclined at an angle and the edge thereof tapered to provide the point **60**. This edge, as described above, allows for concentrating the field lines at a point. The north pole **44**, similarly, is fabricated from a piece of 1.5 millimeter sheet metal stock **86**. All three sheet metal strips, **81**, **82** and **86** are longitudinal and are held together at the upper side thereof by three sheet metal spacers, **88**, **90** and **94**. They are all secured with screws **98**. When the two sheet metal strips **81** and **82** are disposed together, there are two notches **100** and **102** formed therein which provide alignment for the windings **48** and, similarly, the sheet metal strip **86** forming the north pole **44** has two notches **104** and **106** disposed thereon for containing the winding **50**. There are 250 windings of 32 AWG wire for each of the windings **48** and **50**, these being attached to a control system that is operable to activate the windings when a field is desired and deactivate the windings when a field is not desired. The assembled system is illustrated in FIG. **6**. In addition, the electromagnetic shutter can be simplified as seen in FIGS. **7** and **8**. The windings can be attached to only one pole. The net effect is the same.

Referring now to FIG. **7**, there is illustrated the simplified assembled system showing an exploded view of the electromagnetic shutter **40** which utilizes a single pole design. In this design, there is illustrated a first plate **110** with a winding **112** disposed thereabout. The winding **112** is disposed about the longitudinal axis of the plate **110** in an indented area **114** on one side and an indented area **116** on the other side. This comprises the south pole **42** with the sharp edge **60** disposed on the plate **110**. A second plate **117** provides the north pole **44**. Screws **118** are provided to hold the two plates **112** and **117** together. The assembled view is illustrated in FIG. **8**.

In summary, there has been provided an electromagnetic shutter that is utilized in conjunction with a developer module in an electrophotographic print engine. This electromagnetic shutter operates to place a magnetic field in line with the flow of toner particles about a delivery roller in a developer module and extending upward from the surface thereof. When this magnetic field is placed in the path of a developer flow, a magnetic dam is created. This magnetic dam prevents the developer particles from moving out of the delivery port, and therefore, effectively inhibits developer flow.

Although the preferred embodiment has been described in detail, it should be understood that various changes, substitutions and alterations can be made therein without departing from the spirit and scope of the invention as defined by the appended claims.

What is claimed is:

1. A developer module with an electromagnetic shutter, comprising:

a sump housing for containing electrostatic toner particles and having an opening;

a delivery device having a movable surface for conveying developer on said movable surface from the interior of said sump housing to a photoconductive element operable to carry a latent image, said delivery device having a fixed magnetic device associated therewith with at least one pole of a first polarity fixed relative to the movement of said movable surface such that the developer particles are magnetically aligned along said movable surface of said delivery device; and

a magnetic damming device having a surface disposed at a predetermined distance above said movable surface, to create a substantially fixed gap, said magnetic damming device for selectively creating a magnetic field in the path of the developer flow across said gap, thus creating field lines that extend upward from the movable surface of said delivery device from said at least one pole such that the developer particles align themselves with the created magnetic field when selectively created.

2. The developer module of claim **1**, wherein said delivery device comprises a roller.

3. The developer module of claim **2**, wherein said fixed magnetic device comprises a cylindrical magnetic device poled with different magnetic poles having at least one pole of said first polarity and at least one pole of a second polarity opposite said first polarity, such that said electrostatic developer particles magnetically align themselves along the surface of said roller.

4. The developer module of claim **3**, wherein said roller comprises a hollow cylindrical tube of a non-magnetic material.

5. The developer module of claim **1**, wherein said damming device has at least one pole of opposite polarity to said first polarity and disposed above the surface of said delivery device a predetermined distance and proximate to said one pole of said fixed magnetic device, said one pole of said damming device switchable such that said created magnetic field can be turned off and turned on.

6. The developer module of claim **5**, wherein said damming device includes a second pole of said first polarity disposed proximate to said one pole of said damming device of said opposite polarity to said first polarity and disposed such that the field lines created therebetween are substantially parallel to the surface of said delivery device.

7. The developer module of claim **6**, wherein said second pole of said damming device is aligned in an offset position relative to said one pole of said magnetic device.

8. The developer module of claim **7**, wherein said offset is such that said first pole of said damming device lags said one pole of said fixed magnetic device such that the created field lines align the developer particles at an angle that is less than 90° to the flow of developer particles.

9. The developer module of claim **6**, wherein said damming device is operable to have the polarity of said first pole switched to said first polarity and the polarity of said second pole switched to said opposite polarity to alter the characteristics thereof.

10. A method for controlling the flow of developer from a toner housing containing electrostatic developer particles to a delivery device having a movable surface, comprising the steps of:

creating a fixed magnetic device in close association with the surface of the delivery device with at least one pole of a first polarity fixed relative to the movement of the movable surface of the delivery device such that developer particles are magnetically aligned along the movable surface of the delivery device;

disposing a magnetic member above the movable surface of the delivery device to form substantially fixed gap; and

magnetically damming the flow of developer particles from the housing by creating a magnetic field that extends outward from the movable surface of the delivery device and upward from the at least one pole to the magnetic member such that the developer particles align themselves with the created magnetic field to create a dam of developer particles.

11. The method of claim **12**, wherein the delivery device comprises a roller and the fixed magnetic device comprises a cylindrical magnetic device poled with different magnetic poles having at least one pole of the first polarity and at least one pole of a second polarity opposite the first polarity, such that the electrostatic developer particles magnetically align themselves along the surface of the roller.

12. The method of claim **10**, wherein the steps of magnetically damming and disposing the magnetic member above the movable surface of the delivery device disposing an electromagnet above the surface of the delivery device and having at least one pole of the opposite polarity to the fist polarity, at least one pole disposed above the fixed pole associated with the delivery device a predetermined distance and the poles operable to be switched on and off.

13. The method of claim **12**, wherein the electromagnetic has a second pole disposed adjacent to the first pole and above the surface of the delivery device such that the field lines created therebetween are substantially parallel to the surface of the delivery device.

* * * * *